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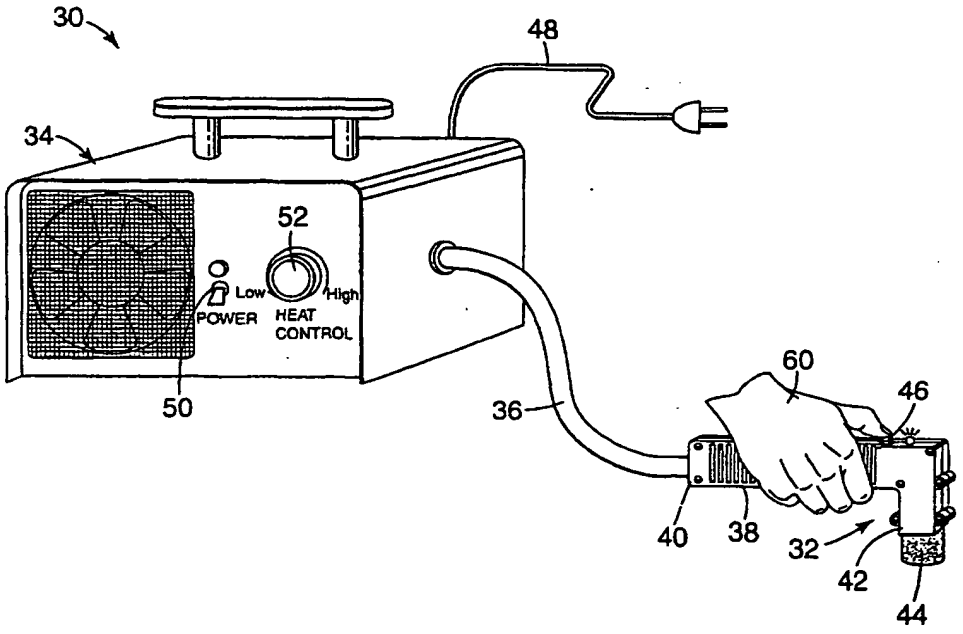
(54) Title: PORTABLE INDUCTION HEATING APPARATUS AND METHOD INCLUDING A HAND HOLDABLE INDUCTION HEATING MEMBER



(57) Abstract: A portable induction heating apparatus and method. The portable induction heating apparatus includes a hand holdable induction heating member including a hand holdable housing having a first end and a second end, and an induction heating mechanism located at the second end. A control unit is provided including a power supply. A flexible cable assembly is provided including a pair of electrical conductors, wherein the power supply is electrically coupled to the induction heating mechanism via the pair of electrical conductors.

PORTABLE INDUCTION HEATING APPARATUS AND METHOD INCLUDING A HAND HOLDABLE INDUCTION HEATING MEMBER

Technical Field

The present invention relates generally to a portable induction heating apparatus and method, and in particular, the present invention is a portable induction heating apparatus and method including a hand holdable induction heating member.

Background of the Invention

Induction heaters are used as a way of heating a metal workpiece. Induction heaters provide high temperature heating of the workpiece without the use of fire (e.g., a torch) or an oven. Known high temperature induction heating systems are very large in size since they require a large power supply. Further, a cooling system is typically necessary due to heating of the induction heater during operation. Due to these size constraints, induction heating systems are not highly portable.

One known portable induction heating system is box-shaped and includes a set of handles for carrying the system. Extending from the box is a relatively large pancake coil heating member. The induction heating system is connected via a power cable to a power supply. Such a portable induction heating system does not lend itself for induction heating of smaller workpieces or workpieces located in very constrained workplaces.

Summary of the Invention

The present invention provides a portable induction heating apparatus and method, and in particular, provides a portable induction heating apparatus including a hand holdable induction heating member.

In one embodiment, the present invention provides a portable induction heating apparatus. The portable induction heating apparatus includes a hand holdable induction heating member including a hand holdable housing having a first end and a second end. An induction heating mechanism is located at the second end. A control unit is provided including an alternating current power supply. A flexible cable assembly is provided including a pair of electrical conductors, wherein the alternating current power supply is

electrically coupled to the induction heating mechanism via the pair of electrical conductors.

The portable induction heating apparatus further includes a control mechanism extending from the housing, operably coupled to the power supply. In one aspect, the control mechanism is operably coupled to the power supply via the flexible cable assembly. The control mechanism is a switch.

In one aspect, the inductive heating mechanism includes a toroid coil and a protective housing positioned over the toroid coil. The protective housing is removable and replaceable with a second protective housing. A coupling mechanism may be provided for coupling the protective housing to the hand holdable housing. In one preferred embodiment, the protective housing is made of a high temperature, rigid polymeric material. The protective housing is generally cup-shaped.

In one aspect, the portable induction heating apparatus further includes a cooling system coupled to the inductive heating mechanism.

Brief Description of the Drawings

The accompanying drawings are included to provide a further understanding of the present invention and are incorporated in and constitute a part of this specification. The drawings illustrate the embodiments of the present invention and together with the description serve to explain the principals of the invention. Other embodiments of the present invention and many of the intended advantages of the present invention will be readily appreciated as the same become better understood by reference to the following detailed description when considered in connection with the accompanying drawings, in which like reference numerals designate like parts throughout the figures.

Figure 1 is a perspective view of an induction heating apparatus in accordance with the present invention.

Figure 2 is a perspective view illustrating one exemplary embodiment of a hand holdable induction heating member in accordance with the present invention.

Figure 3 is a side view illustrating one exemplary embodiment of the hand holdable induction heating member of Figure 2, with a portion of the housing removed.

Figure 4 is a partial side view illustrating one exemplary embodiment of an induction heating member in accordance with the present invention, having a removable protective housing.

Figure 5 is a side view illustrating one exemplary embodiment of an induction heating member in accordance with the present invention, having a removable protective housing.

Figure 6 is a perspective view illustrating another exemplary embodiment of an induction heating member in accordance with the present invention.

Figure 7 is a perspective view illustrating another exemplary embodiment of an induction heating member in accordance with the present invention.

Figure 8 is a perspective view illustrating another exemplary embodiment of an induction heating member in accordance with the present invention.

Figure 9 is a block diagram illustrating one exemplary embodiment of a control unit used in an induction heating apparatus in accordance with the present invention.

Figure 10 is a side view illustrating another exemplary embodiment of an induction heating member in accordance with the present invention.

Figure 11 is a front elevational view of the induction heating member of Figure 10.

Figure 12 is a side view illustrating one exemplary embodiment of the induction heating member of Figure 10 with a portion of the housing removed.

Figure 13 is a side view illustrating one exemplary embodiment of a C-shaped core shown.

Detailed Description

In Figure 1, a portable induction heating apparatus in accordance with the present invention is generally shown at 30. The portable induction heating apparatus 30 includes a hand holdable induction heating member 32, a control unit 34, and a flexible cable assembly 36. The hand holdable induction heating member 32 is flexibly coupled to the control unit 34 via the flexible cable assembly 36. The hand holdable induction heating member 32 is a very small induction heating member, allowing for "spark-free" high temperature heating of workpieces in hard to reach or space limited applications.

The hand holdable induction heating member 32 includes a hand holdable housing 38 having a first end 40 and a second end 42. An induction heating mechanism 44 is

located at the second end 42. The hand holdable induction heating member 32 further includes a control mechanism 46 extending from the hand holdable housing 38, operably coupled to the control unit 34. The control mechanism 46 allows for activation and deactivation of the hand holdable induction heating member 32 remote from control unit 34 at the hand holdable induction heating member 32.

Control unit 34 includes a power supply and cooling system. In one aspect, the power supply is capable of providing power to the heating member 32 for heating a workpiece up to 2000° Fahrenheit. In one preferred aspect, the power supply is a 1500 watt power supply, providing sufficient power to member 32 such that a cooling system is required. The power supply is connectable to a power source via electrical coupling mechanism 48. In one preferred aspect, the electrical coupling mechanism 48 is a power cord, wherein the control unit 34 can be coupled to a standard 120 volt power source. Other power sources may be used for other applications (e.g., 220 volt AC, 408 volt AC, etc.). The control unit 34 further includes a power switch 50 providing for on/off control of the portable induction heating apparatus 30. A heat control mechanism 52 is provided for regulating the amount of heat supplied to a workpiece via the hand holdable induction heating member 32. One exemplary embodiment of the control unit 34, including the power supply and cooling system, will be described in detail later in this specification.

The term "hand holdable" as used herein refers to the characteristics of the hand holdable induction heating member 32 which allow it to be held, operated, and controlled (via control mechanism 46) with one hand, illustrated by user hand 60, without the use of a separate handle or other mechanism. The hand holdable housing 38 allows for the hand holdable induction heating member 32 to be grasped by a user's hand in a manner similar to grasping a hammer or other small tool, and may be grasped without the use of a separate handle. Further, the hand holdable induction heating member 32 can be operated remote from control unit 34 via control mechanism 46 by a user with the same hand used for holding and positioning the hand holdable induction heating member 32 at a workpiece.

In Figure 2, an enlarged perspective view of one exemplary embodiment of the hand holdable induction heating member 32 is shown. In one embodiment illustrated, the hand holdable induction heating member 32 includes a first portion 70 and a second portion 72. The first portion 70 extends in a first direction, and the second portion 72

extends in a second direction different from the first direction. In the exemplary embodiment shown, the first portion 70 is substantially perpendicular to the second portion 72, forming a generally "L-shaped" member.

In one aspect, hand holdable housing 38 is made of a high temperature rated material, preferably a substantially rigid polymeric material, and more preferably, is made of a high temperature rated polymeric material. In one aspect, the hand holdable housing 38 is made of a phenolic laminate. The hand holdable housing 38 includes a first molded member 74 and a second molded member 76. The first molded member 74 is attached to the second molded member 76 via coupling assemblies 78 (i.e., screws). Gripping surface 80 may also be provided to aid in holding the hand holdable induction heating member 32.

The hand holdable induction heating member is preferably the size of a hand tool suitable for use on workpieces located in constrained workplaces. In one exemplary embodiment, the length of the hand holdable induction heating member is less than ten inches, having a substantially rectangular first portion with a first width of approximately one inch and a second width of approximately one and one-half inches. In one preferred embodiment, the first portion has a length of eight and three-eighths inches and the second portion has a length of three and seven-eighths inches. Preferably, the overall length of the hand holdable induction heating member is between four inches and twelve inches. The exact size of the hand holdable induction heating member can be varied to meet a desired application.

Control mechanism 46 extends from the hand holdable housing 38. In one aspect, the control mechanism 46 is a push-button switch. Further, an activation indicator 82 may be provided (e.g., a light emitting diode (LED)). The activation indicator 82 is operably coupled to control mechanism 46 for providing an indication to the user when the hand holdable induction heating member 32 is activated.

Induction heating mechanism 44 is located at the second end 42 of second portion 72. In one aspect, the induction heating mechanism 44 extends from the second end 42, and includes a work surface 84 positionable adjacent a workpiece to be heated.

In Figure 3, a side view illustrating one exemplary embodiment of hand holdable induction heating member 32 is shown with first molded member 74 removed. The flexible cable assembly 36 is coupled to first end 40 of hand holdable housing 38 via fitting 90. The flexible cable assembly 36 includes a pair of flexible electrical conductors

92, and flexible cooling lines 94. The flexible electrical conductors 92 are coupled to the power supply at control unit 34, and the flexible cooling lines 94 coupled to the cooling system at control unit 34 via the flexible cable assembly 36. In one aspect, the flexible electrical conductors 92 are a polytetrafluoroethylene (PTFE) teflon coated stranded magnet wire. The flexible cooling lines 94 are made of a flexible nylon material to form water-tight tubular members for passing a coolant (e.g., a water/glycol blend) therethrough for cooling of the induction heating mechanism 44.

In particular, a rigid combination fitting 100 is positioned within hand holdable housing 38, and in one embodiment is located at the second portion 72. The combination fitting 100 operates to couple the flexible electrical conductors 92 and the flexible cooling lines 94 to the induction heating mechanism 44. In particular, flexible electrical conductors 92 extend into hand holdable housing 38 at first end 40. The flexible electrical conductors 92 extend through the first portion 70 and couple to combination fitting 100 via electrical conductor 104. Similarly, flexible cooling lines 94 extend into hand holdable housing 38 at first end 40. The flexible cooling lines 94 extend through the first portion 70 and couple to combination fitting 100 at cooling system connector 102. At combination fitting 100, the separate flexible electrical conductors 92 and flexible cooling lines 94 are directed into a single tubing 106 which operates as both an electrical conductor and provides for circulating the coolant therethrough. Preferably, the tubing 106 is an electrically insulated copper tubing. The combination fitting 100 extends into the induction heating mechanism 44.

At induction heating mechanism 44, the tubing 106 is positioned in a multi-turn wrap (i.e., a solenoid construction) about core 110. Core 110 is preferably a ferrite core. The windings 108 and rod-shaped core 110 are located within a high temperature-rated material to form a core assembly, which in one preferred embodiment is encapsulated in a thermally conductive epoxy.

The induction heating mechanism or applicator 44 further includes a protective housing 114 positioned over the core assembly 112. In one aspect, the protective housing 114 is substantially cup-shaped (or crucible shaped), and made of a high temperature material. In one embodiment, the high temperature material is a polymeric material. In one preferred embodiment, the high temperature material is a high temperature rated ceramic (e.g., a magnesium oxide ceramic). The protective housing 114 includes sidewall

116 and work surface 84. The work surface 84 is typically positioned adjacent a workpiece during activation of the hand holdable induction heating member 32. The work surface 84 is preferably very thin to maximize the field of the workpiece, and in one embodiment has a thickness which ranges between .020 and .100 inches.

Control mechanism 46 and activation indicator 82 both extend through hand holdable housing 38. Control mechanism 46 and activation indicator 82 are electrically coupled to control unit 34 via control lines 120 (partially shown). The control lines 120 extend through the housing first portion 70, and are routed through the flexible cable assembly 36 to the control unit 34. In one preferred embodiment, the control mechanism 46 is a "hold on" push-button switch. In order to activate the induction heating mechanism 44, an operator depresses control mechanism 46, which will also light up activation indicator 82. In order to maintain activation of the hand holdable induction heating member 32, an operator must continue to depress the control mechanism 46. Upon releasing the control mechanism 46, the hand holdable induction heating member 32 is no longer activated and the activation indicator 82 goes off. During activation of the hand holdable induction heating member 32, the induction heating mechanism 44 operates to inductively heat a workpiece 122, indicated by field lines 124. Since the induction heating mechanism 44 is typically positioned immediately adjacent the workpiece 122, the induction heating mechanism 44 becomes very hot due to both conductive heating from the workpiece and from the current passing through the induction heating mechanism. The cooling system operates to cool the induction heating mechanism 44 via the passing or cycling of coolant through flexible cooling lines 94 and windings 108.

Figure 4 and Figure 5 illustrate one exemplary embodiment of induction heating mechanism 44 in which protective housing 114 is easily removable and replaceable. During repeated operations of the hand holdable induction heating member 32, the protective housing 114 may experience wear due to extreme temperature cyclings and contacting of heated workpieces.

In Figure 4, the protective housing 114 is shown positioned over the toroid windings 108 and core 110. An attachment mechanism 126 is provided for removably attaching the protective housing 114 to the hand holdable housing 38. In the exemplary embodiment shown, the attachment mechanism 126 is a set screw mechanism. The attachment mechanism 126 securely holds the protective housing 114 over core assembly

112, encapsulating the windings 108 and core 110. In reference to Figure 5, attachment mechanism 126 is operated to release the protective housing 114 from the hand holdable housing 38. Further, if the protective housing 114 is damaged, the protective housing 114 may be easily replaced with a second protective housing and again secured into place about the core assembly 112 using attachment mechanisms 126. Other attachment mechanisms may be used, such as providing a lip or other projection in protective housing 114 which releasably engages with the hand holdable housing 38. Other attachment mechanisms will become apparent to those skilled in the art after reading this application.

It is recognized that the hand holdable induction heating member 32 may be alternately configured as desired for different applications. In reference to Figure 6, a side view illustrating one exemplary alternate embodiment of a hand holdable induction heating member is shown at 132. The hand holdable induction heating member 132 is similar to the hand holdable induction heating member 32 previously described herein. The hand holdable induction heating member 132 includes a first portion 134 and a second portion 136. The first portion 134 extends in a first direction, and the second portion 136 extends in a second direction different from the first direction which is not substantially perpendicular to the first direction. In Figure 7, a side view illustrating another exemplary embodiment of a hand holdable induction heating member in accordance with the present invention is shown at 140. The hand holdable induction heating member 140 is similar to the hand holdable induction heating member 32 previously described herein. The hand holdable induction heating member 140 includes a first portion 142 and a second portion 144. The first portion 142 and second portion 144 extend longitudinally in substantially the same direction to form a "wand-like" member.

In Figure 8, a side view illustrating another exemplary embodiment of a hand holdable induction heating member in accordance with the present invention is generally shown at 150. The hand holdable induction heating member 150 is similar to the hand holdable induction heating member 32 previously detailed herein. The hand holdable induction heating member 150 includes an induction heating mechanism 152 having a different configuration than the induction heating mechanism 44 previously described herein. The induction heating mechanism 152 extends from hand holdable housing 38, and may comprise a "pancake-shaped" heating member or coil, a round, rectangular, formed spiral, helical, internal, U-shaped or toroid shaped heating member, or other coil

configuration. Other configurations for induction heating mechanism 152 will become apparent to those skilled in the art after reading the present application.

In Figure 9, one exemplary embodiment of control unit 34 is illustrated. Control unit 34 includes cooling system 160 and power supply and control 162. In one embodiment, cooling system 160 includes a heat exchanger having cooling fan 164. In one preferred embodiment, the cooling system includes an air over water recirculating heat exchanger. Cooling system 160 operates to cool hand holdable induction heating member 32, and is mechanically coupled to the induction heating mechanism 44 via the supply and return flexible cooling lines 94. During operation of the hand holdable induction heating member 32, the cooling system 160 operates to circulate coolant (e.g., a water/glycol coolant) through the hand holdable induction heating member 32, reducing or eliminating the possibility of heat damage to the hand holdable induction heating member 32. A flow switch may be provided at control unit 34 in the cooling lines to sense loss of flow in the cooling lines. In response, an alarm may be triggered or power to the hand holdable induction heating member 32 can be shut off. Power supply and control 162 provides power to the hand holdable induction heating member 32 via flexible electrical conductors 92. Further, power supply and control 162 provide for remote activation of the hand holdable induction heating member 32 via control lines 120. In one preferred embodiment, the flexible electrical conductors 92, flexible cooling lines 94, and control lines 120 are routed to hand holdable induction heating member 32 via flexible cable assembly 36.

At control unit 34, power switch 46 is provided for on/off control of power supply and control 162. Further, heat control mechanism 52 (e.g., a rheostat) is provided to control the power output to induction heating mechanism 44, thereby controlling the heat output of the induction heating mechanism 44. In one preferred embodiment, the power supply is an AC to DC to AC high frequency inverter which provides a pulsed high frequency output to the induction heating mechanism 44. At one embodiment, power is output to the induction heating mechanism 44 at a constant frequency, but having a variable output pulse rate frequency. By increasing the frequency of pulses to induction heating mechanism 44, the power is increased. In one aspect, the heat control mechanism 52 is operated to vary the frequency of the pulses between 2.5 kiloherz and 20 kiloherz.

In Figure 10, another exemplary embodiment illustrating a hand holdable induction heating member in accordance with the present invention is illustrated at 170. The hand holdable induction heating member 170 is operated at a lower temperature than the induction heating members previously described herein and as such does not require a separately supplied cooling system. In an alternate embodiment, hand holdable induction heating member 170 may be operated at higher temperatures, and include a cooling system which can be similar to the cooling system previously described herein.

In one preferred embodiment, hand holdable heating member 170 is supplied with up to 500 watts of power. The hand holdable induction heating member 170 includes a hand holdable housing 172 having a first portion 176 and a second portion 178. Extending from the hand holdable housing 172 at the first portion 176 is a control mechanism 180 for controlled activation of the hand holdable induction heating member 170. Located at second portion 178 is an encapsulated induction heating mechanism 182. The encapsulated heating mechanism 182 includes an outer shell made of a high temperature material, and in one preferred embodiment, is made of a molded phenolic ceramic material. In reference also to Figure 11, extending through the shell 184 are vent openings 185. Vent openings 185 operate to naturally air cool the hand holdable induction heating member 170.

The induction heating mechanism 182 is generally C-shaped, and includes an opening 186. About the opening 186 are wear surfaces 188, 190, 192. In one preferred embodiment, the wear surfaces are coated, and more preferably, are ceramic coated.

In Figure 12, the hand holdable induction heating member 170 is shown with a portion of the hand holdable housing 172 removed. Flexible electrical conductors 92 and control lines 120 extend longitudinally through first portion 176. Referring also to Figure 13, the second portion 178 includes a C-shaped core 200 (i.e., a toroid or gap toroid core), which is preferably a ferrite core. The core 200 includes a core gap 202 which is positioned at opening 186. Flexible electrical conductors 92 are wound about the core 200, indicated at 204, to form an induction heating assembly.

A workpiece 206 is shown positioned immediately adjacent the opening 186 (at 202). Upon activation of the hand holdable induction heating member 170 via control mechanism 180, magnetic flux will cross the core gap 202, indicated by field lines 208. Workpiece 206, made of a magnetically permeable material, will draw the magnetic flux

by providing a path of least reluctance through which the flux will travel. Accordingly, the hand holdable induction heating member 170 operates to inductively heat the workpiece 206.

The portable induction heating apparatus in accordance with the present invention is useful in most any application which requires quick heating of a metallic workpiece. In one aspect, the present invention is useful for heating of a thermally responsive material (e.g., thermally responsive adhesives or sealants) for bonding, debonding or other heat required applications. In one embodiment, the portable induction heating apparatus in accordance with the present invention is useful for heating a thermally responsive material along a substantially continuous bondline as disclosed in U.S. Patent Application No. 09/422,608 to Lappi et al. filed on the same day as the present application. The entire contents of this referenced application are incorporated herein by reference. In this application, the portable induction heating apparatus in accordance with the present invention may be used to accelerate the curing of a substantially continuous bondline along the entire length of the bondline, or may be used to "spot cure" at desired locations along the continuous bondline. In this aspect, the bondline is spot heated or "tacked" at desired locations to a structural strength required to maintain the position of the workpieces, while allowing the remaining portion of the continuous bondline to cure over time. The spot heating or tacking method of using the portable induction heating apparatus in accordance with the present invention is useful in bonding applications using a paste-type of temporary adhesive. Further, the portable induction heating apparatus in accordance with the present invention is useful in heating or melting other thermally responsive materials, such as the hot melting of sealants.

Additionally, the portable induction heating apparatus in accordance with the present invention is useful in many debonding applications. The portable induction heating apparatus is positioned adjacent a bond or bondline, for inductive heating of the bond or bondline to a temperature sufficient to release the bond and/or separate bonded workpieces.

The portable induction heating apparatus in accordance with the present invention operates to inductively "spot heat" in a broad number of applications. Such applications include heating a thermally responsive material (including adhesives or sealants) along a continuous bondline, hot melting of sealants, debonding of thermally responsive materials,

quick heating of frozen workpieces (e.g., a frozen lugnut) without causing heat damage to adjacent areas. Other applications may include the heating for subsequent removal of sealants, melting of "set" adhesives, heating of pinstriping for removal from automobiles, or other torch-free or chemical-free applications. Other operations and useful applications of the portable induction heating apparatus in accordance with the present invention will become apparent to those skilled in the art after reading the present application.

Numerous characteristics and advantages of the invention have been set forth in the foregoing description. It will be understood, of course, that this disclosure is, and in many respects, only illustrative. Changes can be made in details, particularly in matters of shape, size and arrangement of parts without exceeding the scope of the invention. The invention scope is defined in the language in which the appended claims are expressed.

WHAT IS CLAIMED IS:

1. A portable induction heating apparatus comprising:

a hand holdable induction heating member including a hand holdable housing having a first end and a second end, and an induction heating mechanism located at the second end;

a control unit including a power supply; and

a flexible cable assembly including a pair of electrical conductors, wherein the power supply is electrically coupled to the induction heating mechanism via the pair of electrical conductors.

2. The apparatus of claim 1, further comprising a control mechanism extending from the housing, operably coupled to the power supply.

3. The apparatus of claim 2, wherein the control mechanism is operably coupled to the power supply via the flexible cable assembly.

4. The apparatus of claim 3, wherein the control mechanism is a switch.

5. The apparatus of claim 2, wherein the inductive heating mechanism includes a toroid coil and a protective housing positioned over the toroid coil.

6. The apparatus of claim 5, wherein the protective housing is removable and replaceable with a second protective housing.

7. The apparatus of claim 6, further comprising a coupling mechanism for coupling the protective housing to the hand holdable housing.

8. The apparatus of claim 6, wherein the protective housing is made of a high temperature, rigid polymeric material.

9. The apparatus of claim 5, wherein the protective housing is generally cup-shaped.

10. The apparatus of claim 1, further comprising a cooling system coupled to inductive heating mechanism.

11. A method of tack bonding two juxtaposed members, including reducing the curing time of a thermally responsive bonding material positioned adjacent a first member which defines a substantially continuous first bondline, wherein the first member is made of an electrically conductive material or positioned adjacent an electrically conductive material, comprising the steps of :

Providing a portable induction heating apparatus including a hand holdable induction heating member including a hand holdable housing having a first end and a second end, and an induction heating mechanism located at the second end, a control unit including a power supply, and a flexible cable assembly including a pair of electrical conductors, wherein the power supply is electrically coupled to the induction heating mechanism via the pair of electrical conductors;

Positioning the hand holdable induction heating member adjacent the first member along the first bondline at a first location;

Activating the power supply to inductively heat the electrically conductive material for conductive heating of the thermally responsive material for a desired amount of time at the first location.

12. The method of claim 11, further comprising the step of moving the hand holdable induction heating member to a second location along the first bondline, for inductive heating at the second location via the hand holdable induction heating member.

13. The method of claim 11, further comprising the step of operating the power supply via a control mechanism extending from the hand holdable housing.

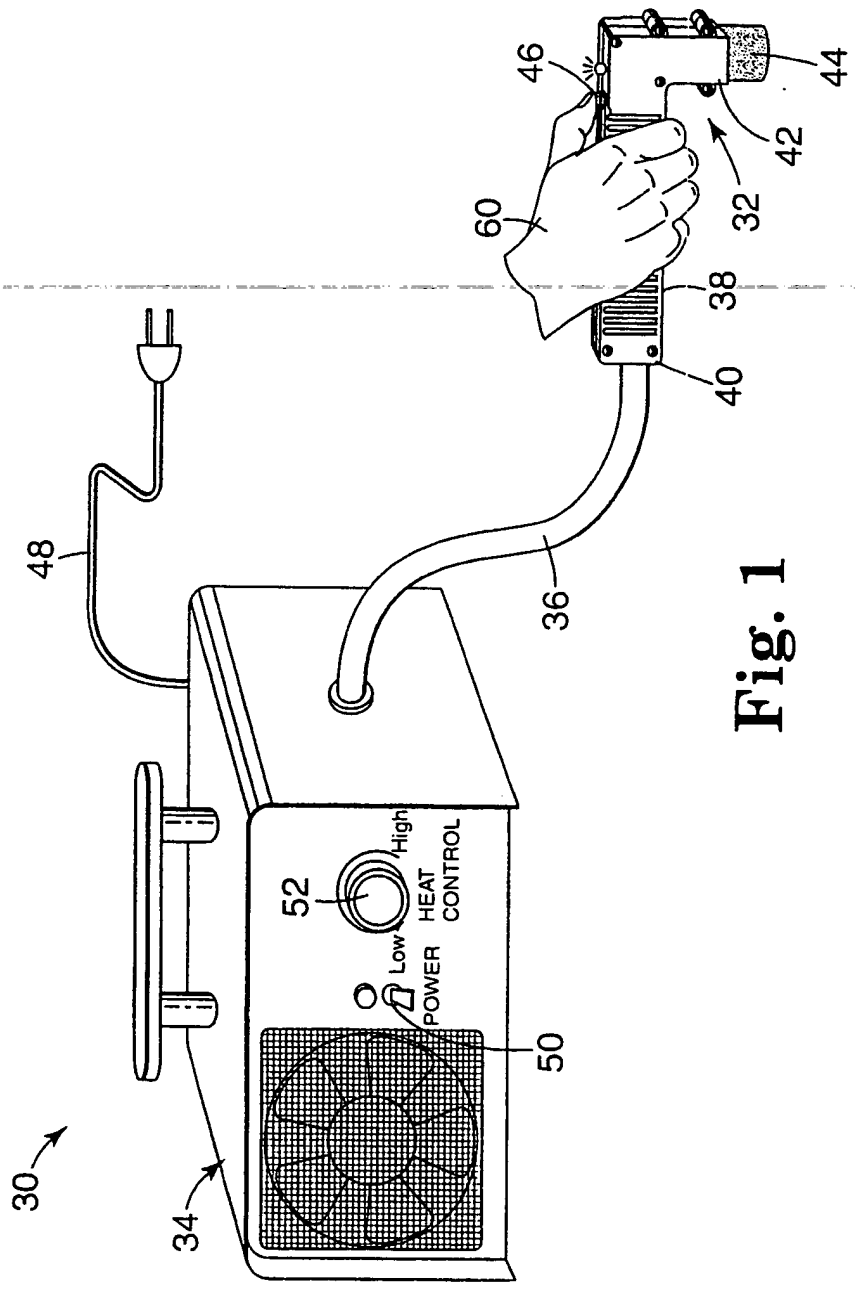


Fig. 1

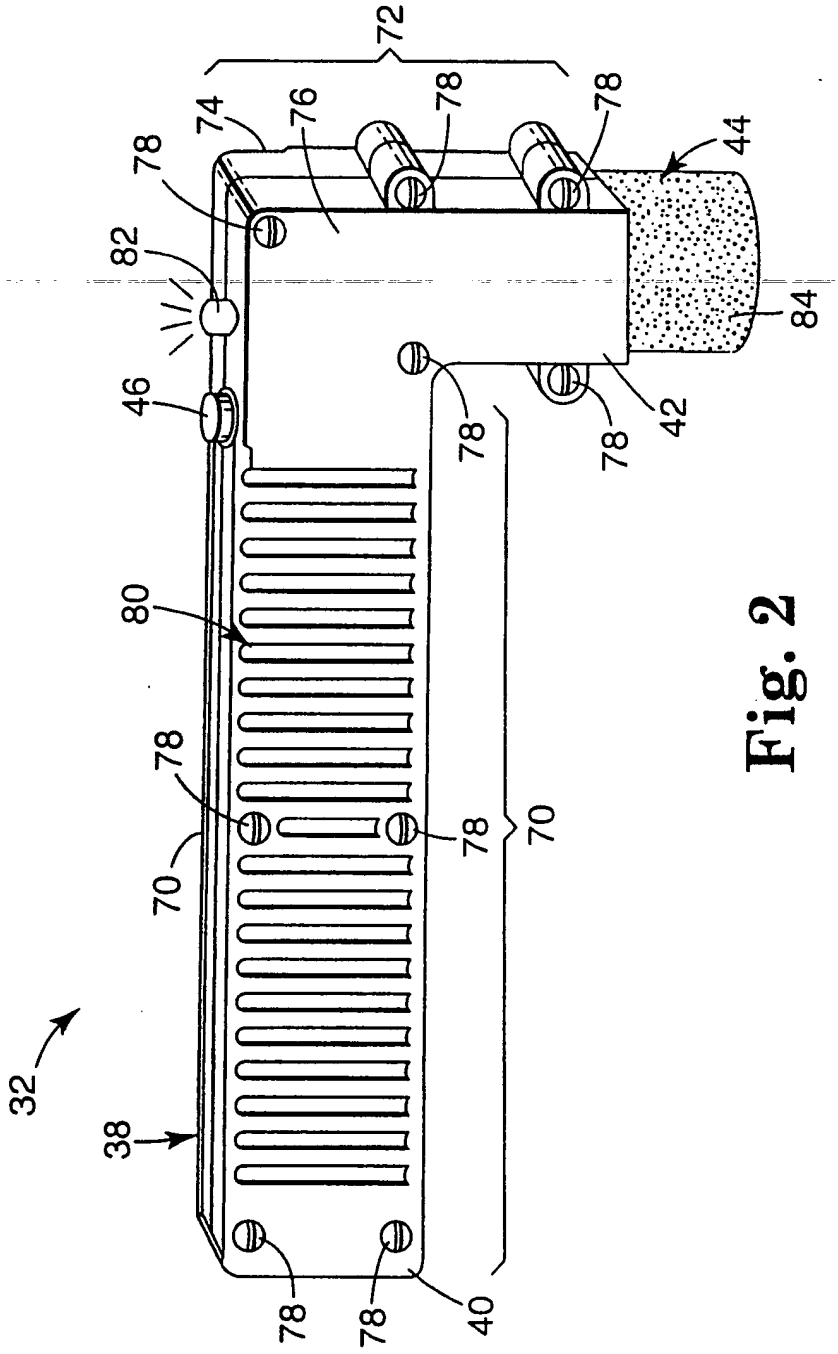


Fig. 2

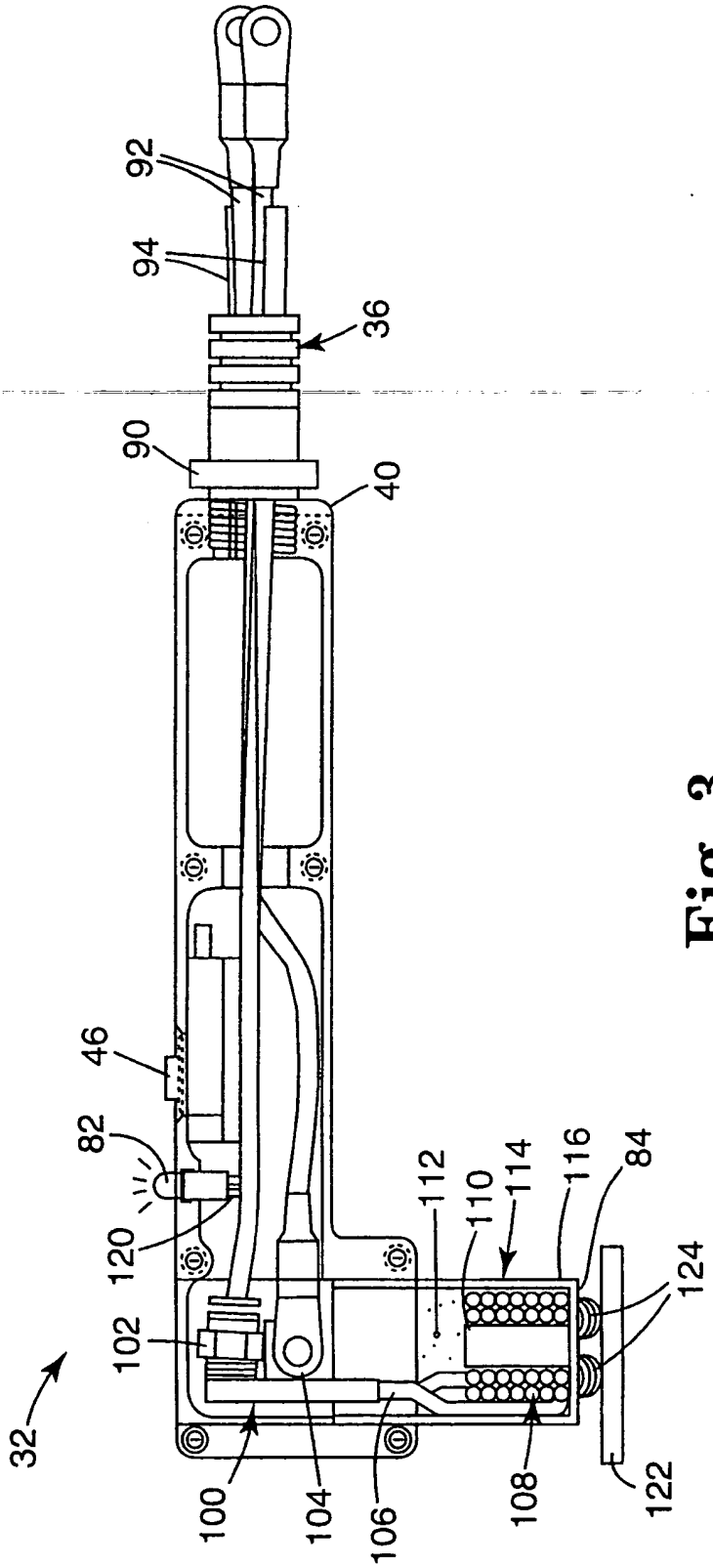


Fig. 3

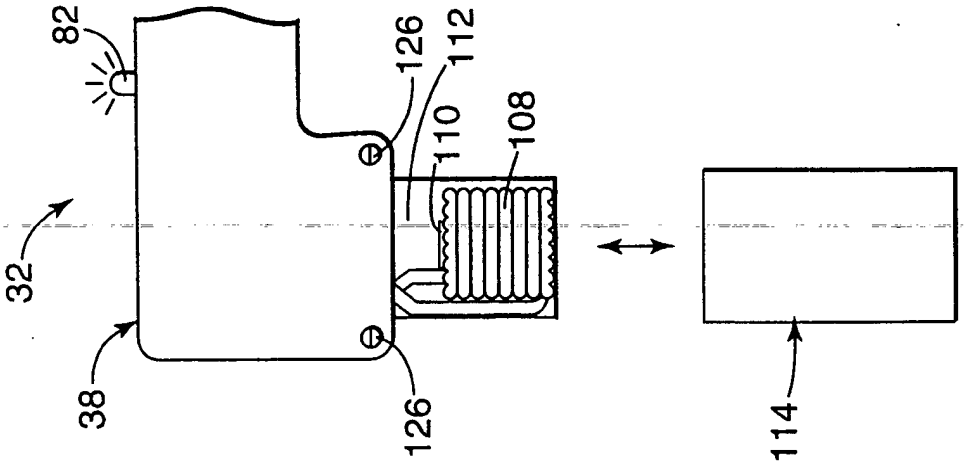


Fig. 5

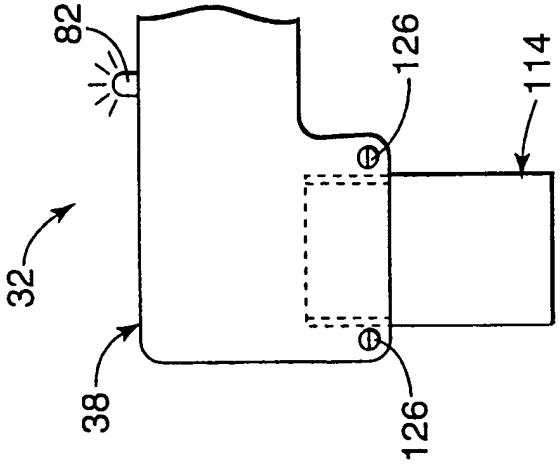


Fig. 4

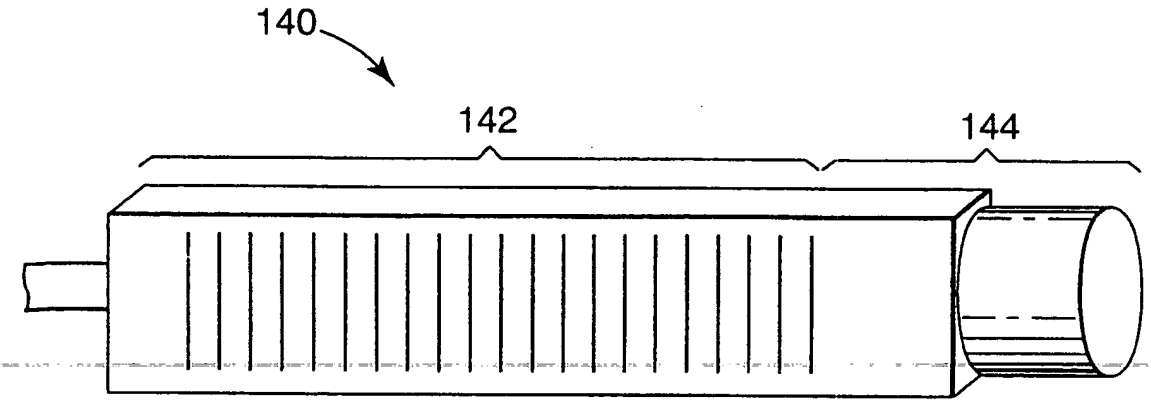


Fig. 7

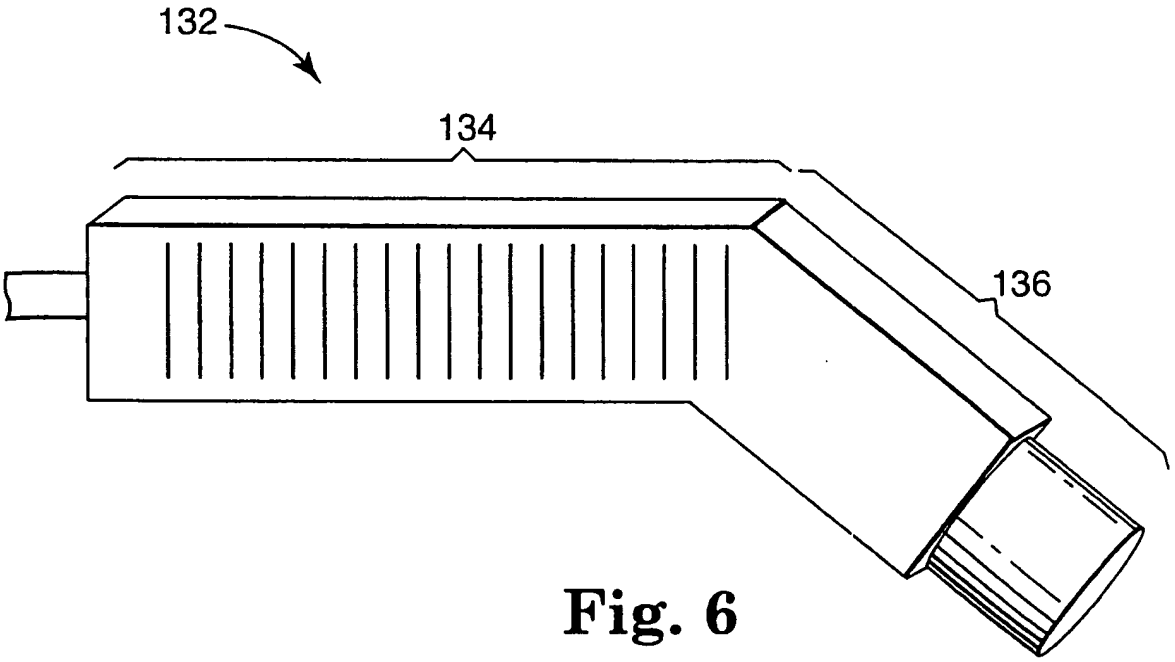


Fig. 6

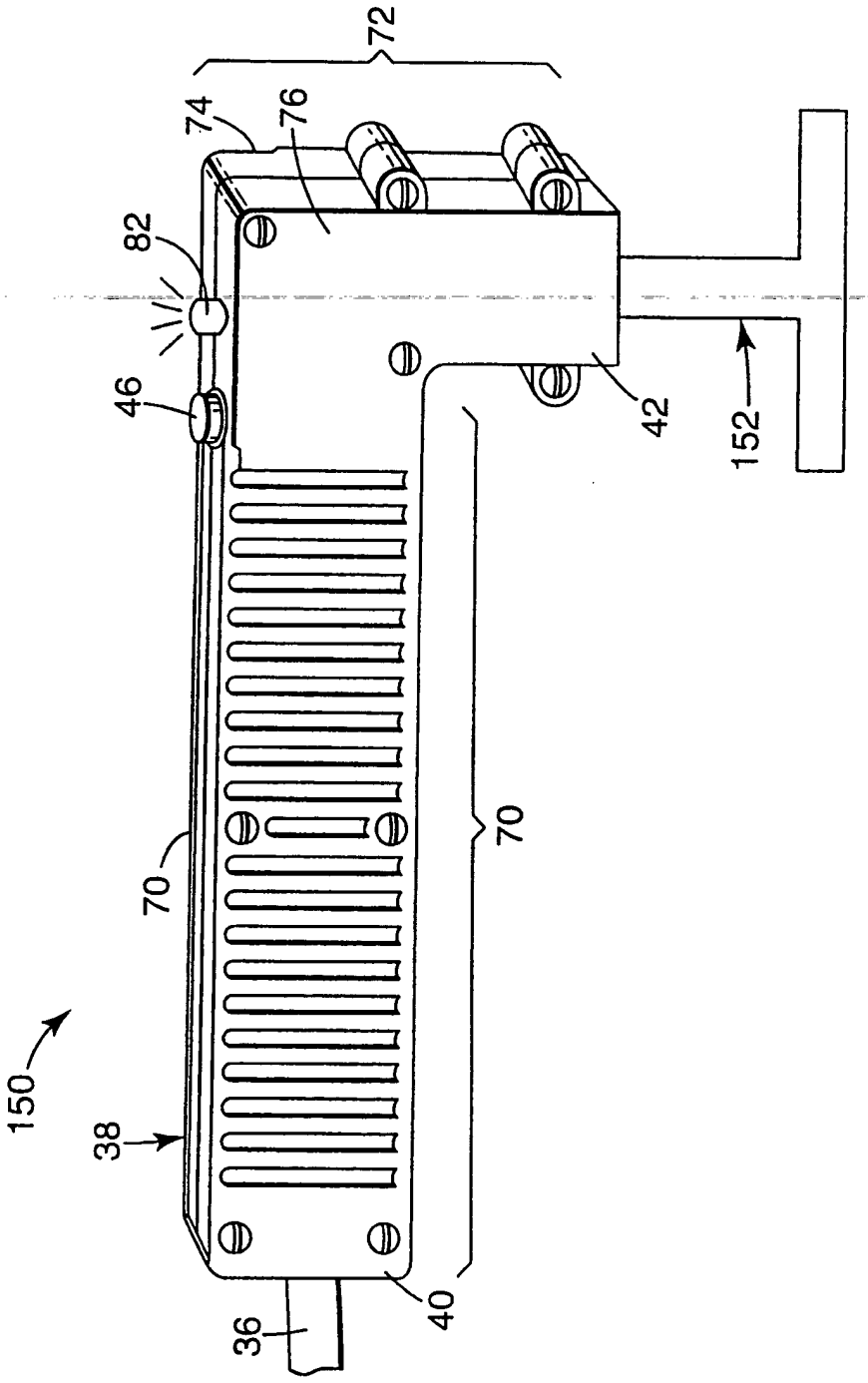


Fig. 8

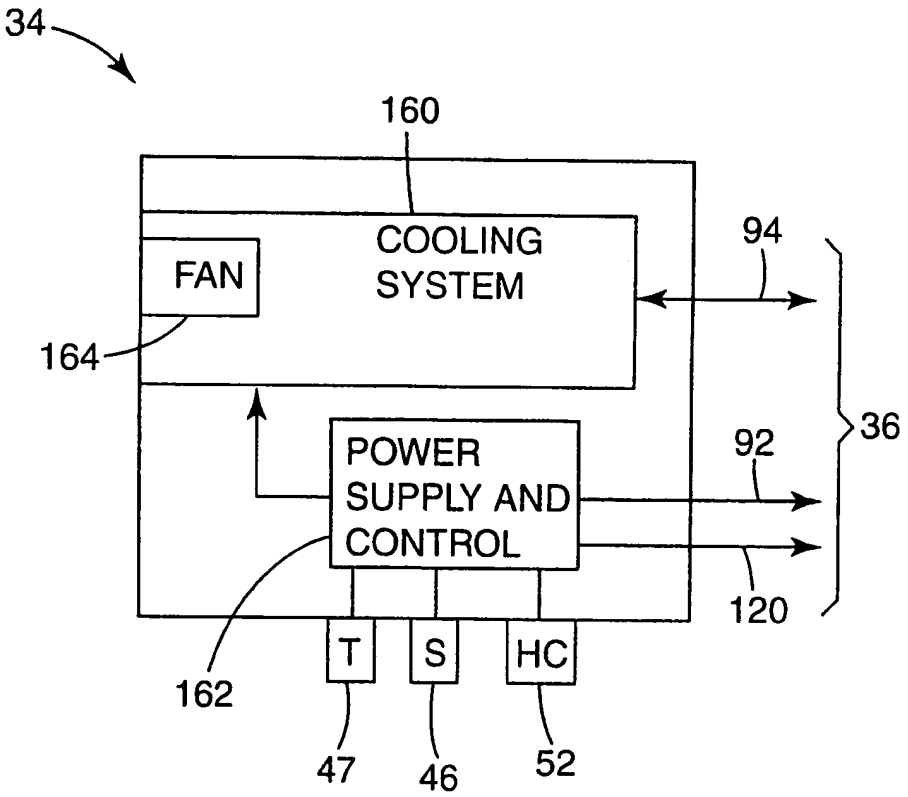

34
160
COOLING SYSTEM
FAN
164
94
36
POWER SUPPLY AND CONTROL
92
120
T
S
HC
162
47
46
52

Fig. 9

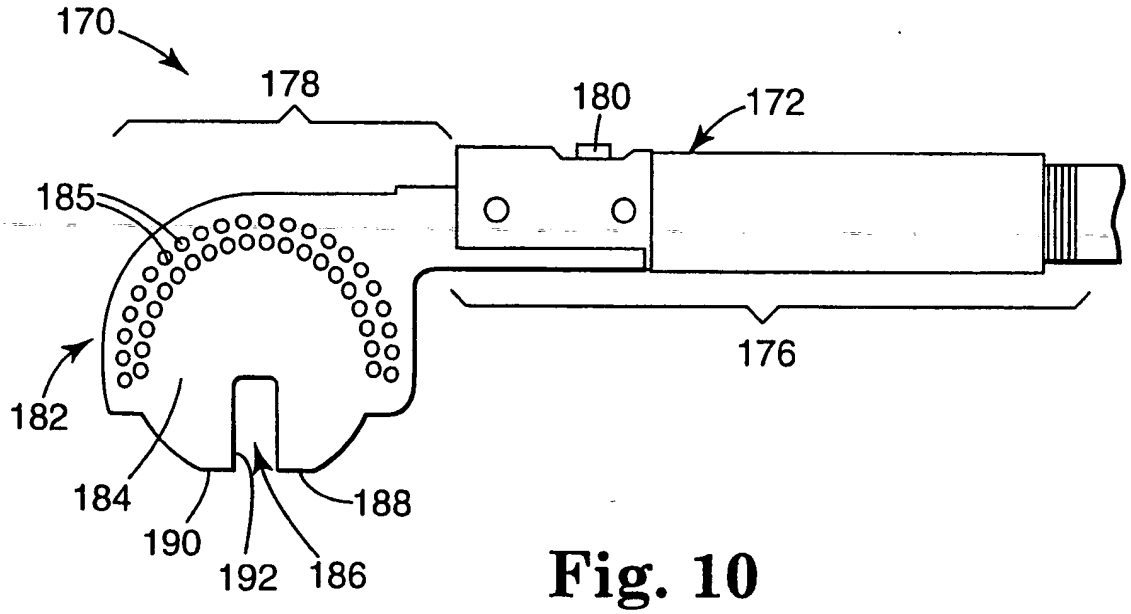


Fig. 10

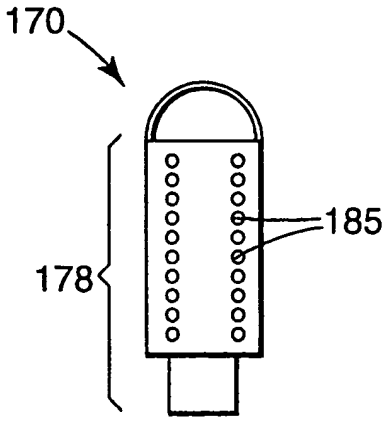


Fig. 11

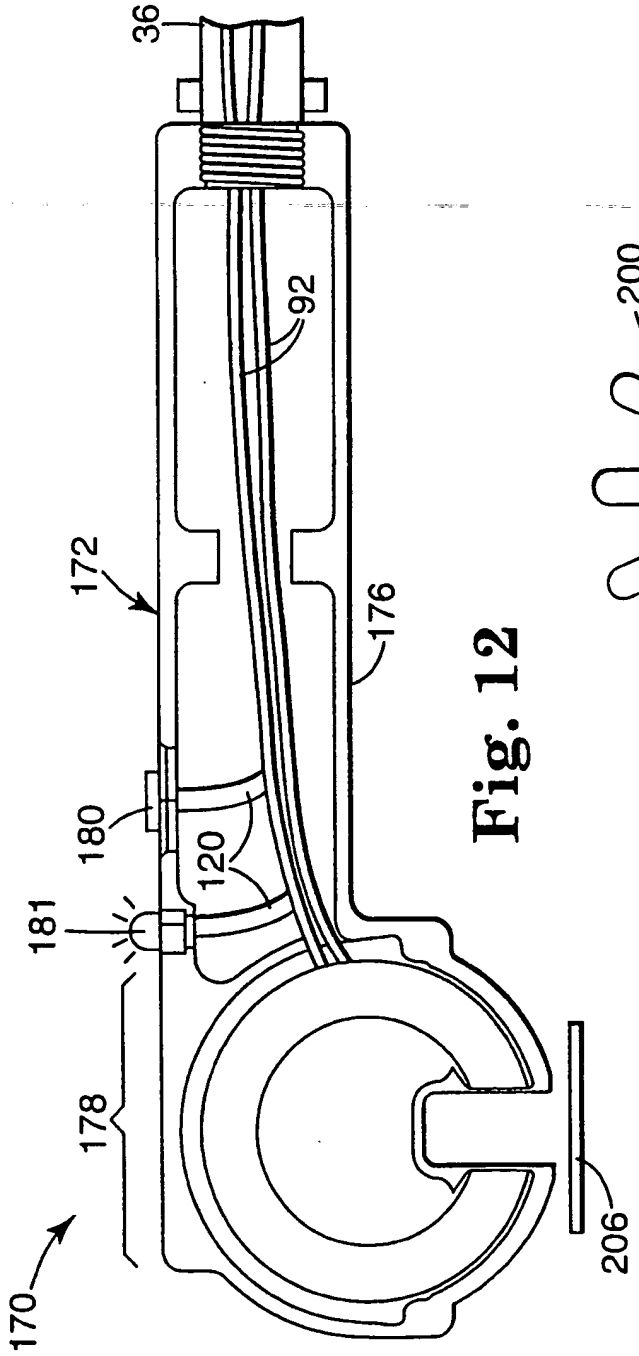


Fig. 12

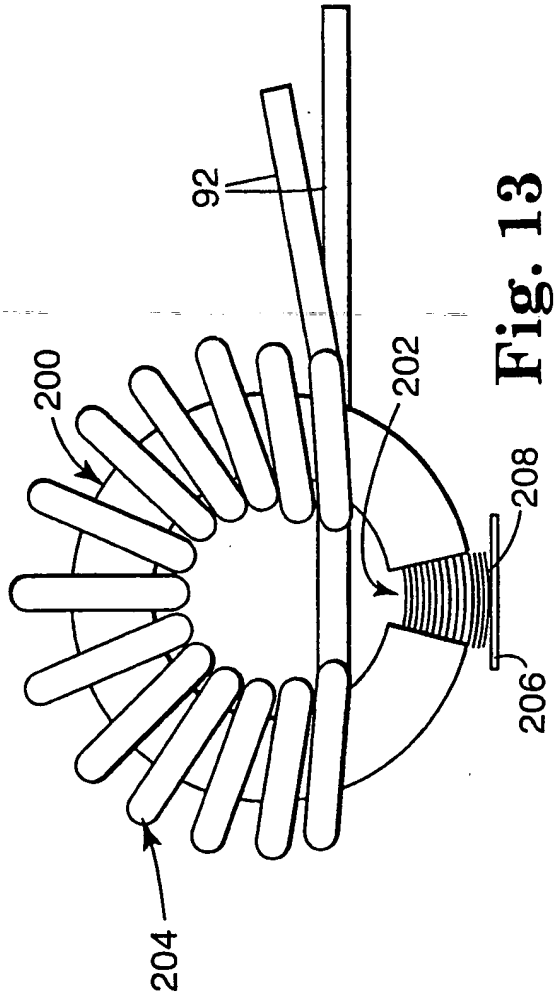


Fig. 13

INTERNATIONAL SEARCH REPORT

Int. ional Application No
PCT/US 00/27835

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H05B6/10 H05B6/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 374 809 A (COULTRIP ROBERT H ET AL) 20 December 1994 (1994-12-20) abstract column 3, line 5 - line 36 column 4, line 6 -column 5, line 40	1-5
X	WO 87 00123 A (TAYLOR WINFIELD CORP) 15 January 1987 (1987-01-15) the whole document claim 1; figure 4	11-13

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
23 January 2001	30/01/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Taccoen, J-F

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Int. ional Application No
PCT/US 00/27835

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5374809 A	20-12-1994	NONE	
WO 8700123 A	15-01-1987	US 4528057 A	09-07-1985